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Overview of Subsurface Constructed Wetlands Application in Tropical Climates

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Abstract:

Subsurface flow constructed wetlands (SFCW) have specific capacity to absorb and retain particulate matters, nutrients and other pollutants which enters water bodies through surface runoff, domestic wastewater, industrial wastewater and also from plantations. However, as the field becomes more relevant towards sustainability environment, the SFCW study is often significant for developing countries with tropical climates where the zones are warm and humid weather in all years. SFCW showed an increase rate of contaminant up-take in warmer climates; therefore this treatment has been expected to operate more efficiently in tropical regions. SFCW recent technologies are also excellent in the utilisation of natural processes and the high process stability which contributing a high nutrient capturing capacity. Furthermore, the systems are simple to construct and less expensive option than aquatic plant systems which is a benefit in many developing countries. Accordingly, this paper highlights some SFCW applications on nutrients capturing capabilities (nitrogen and phosphorus), general view on construction, operation and maintenance of the SFCW and vegetation selection for start-up. In addition, application of different wastewater types such as landfill leachate, domestic wastewater and industrial wastewater are also discussed in brief. Future considerations in choosing appropriate technology aspect of wetlands applications such geographic information system (GIS), compost material and bio-particle are highlighted.

Keyword: Bioparticle, Compost Material, Geographic Information System, Subsurface Flow Constructed Wetlands, Tropical Climates

1.0 Introduction:

Constructed wetlands have been used widely for the treatment of municipal, industrial and agricultural wastewater, as well as for urban storm water. This is owing to their high nutrient absorption capacity, simplicity, low construction, operation and maintenance costs, low energy demand, process stability, low excess sludge production and potential for creating biodiversity (Korkusuz *et al.,* 2005). Properly designed and constructed man-made wetland ecosystems are extremely efficient at utilizing and cleaning nutrient-rich waters (Mitsch and Gosselink, 1993). Moreover, it has gained increasing acceptance for many types of bioremediation, including mining and agribusiness wastewater (Hammer, 1989; EPA, 1993; Reed *et al.,* 1995).

In general, there are two basic types of constructed wetlands, the free water surface (FWS) wetland and the subsurface flow (SF) wetland (Figure 1). Both types utilize emergent aquatic vegetation and are similar in appearance to a marsh. The FWS wetland typically consists of a basin or channels with some type of barrier to prevent seepage, soil to support the roots of the emergent vegetation, and water at a relatively shallow depth flowing through the system. The water surface is exposed to the atmosphere, and the intended flow path through the system is horizontal.

The SF wetland consists of a basin with a barrier to prevent seepage, but the bed contains a suitable depth of porous media. Rock or gravel is the most commonly used media types. The media support the root structure of the emergent vegetation. The design of these systems assumes that the water level in the bed will remain below the top of the rock or gravel media. The FWS systems have the advantage of requiring less land area for wastewater treatment (Nelson *et al.,* 2003). Moreover, they have the ability to filter, absorb and retain particulate matters, nutrients or other pollutants in wastewater. Table 1 illustrates the type of wetlands, vegetation types and water column contacts in constructed wetlands.

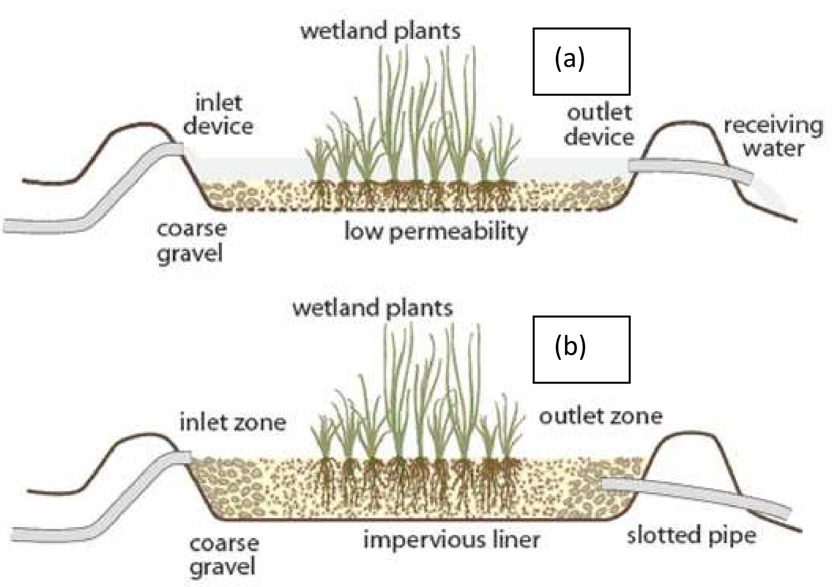

Figure 1: Type of Constructed Wetland (A) Free Water Surface (B) Subsurface Flow (Adapted from Gearheart, 2006)

Table 1: Vegetation Type and Water Column Contact in Constructed Wetlands

Constructed Wetland Type	Type of Vegetation	Section in Contact with Water Column
Free water surface (FWS)	Emergent	Stem, limited leaf contact
	Floating	Root zone, some stem / tubers
	Submerged	Photosynthetic part, possibly root zone
Sub-surface flow (SSF)	Emergent	Rhizome and root zone

The subsurface flow constructed wetlands (SFCW) first emerged as a wastewater treatment technology in Western Europe based on research by Seidel (1966) commencing in the 1960s and by Kickuth (1977) in the late 1970s and early 1980s. Early developmental work in the United States commenced in the early 1980s with the research of Wolverton *et al*. (1983) and Gersberg *et al*. (1985). At present, a typical SFCW has been widely applied in tropical climates such as in Thailand, India and Indonesia. However in Malaysia, the application of SFCW has not been implemented since many research focuses into small scale system (Katayon *et al.,* 2008). Many countries in African continental which has tropical climates use constructed wetland for wastewater treatment (e.g. Tanzania, Kenya, Malawi, Uganda, Zambia, Botswana, Zimbabwe). However, many of these systems have been performing below the required standards, due to lack of proper operation and maintenance (Kayombo *et al*., 1998). Constructed wetlands have not yet received the deserved attention as an alternative method for wastewater treatment.

SFCW systems are most appropriate for treating primary wastewater, because there is no direct contact between the water column and the atmosphere. There is no opportunity for vermin to breed, and the system is safer from a public health perspective. The system is particularly useful for treating septic tank effluent or grey water, landfill leachate and other wastes that require removal of high concentrations organic materials, suspended solids, nitrate, pathogens and other pollutants. The environment within the SFCW bed is mostly either anoxic or anaerobic. Oxygen is supplied by the roots of the emergent plants and is used up in the biofilm growing directly on the roots and rhizomes, being unlikely to penetrate very far into the water column itself. SFCW systems are good for nitrate removal (denitrification), but not for ammonia oxidation (nitrification), since oxygen availability is the limiting step in nitrification. Generally, there are two types of SFCW systems: horizontal flow SFCW and vertical flow SFCW. The most common problem with horizontal flow is blockage, particularly around the inlet zone, leading either to short circuiting, surface flow or both. This occurs because of poor hydraulic design, insufficient flow distribution at the inlet, and inappropriate choice of porous media for the inlet zone.

2.0 Nutrient Capturing Capacity:

2.1 Nitrogen:

The dominant forms of nitrogen (N) in wetlands which are important to wastewater treatment include organic nitrogen, ammonia, ammonium, nitrate, nitrite, and nitrogen gases. Inorganic forms are essential to plant growth in aquatic systems but if the amount limited it can affect plant productivity. The nitrogen entering wetland systems can be measured as organic nitrogen, ammonia, nitrate and nitrite. Ammonia is oxidized to nitrate by nitrifying bacteria in aerobic zones which typically occurs at the above soil level. The oxygen required for nitrification is supplied by transmission from the atmosphere and leakage from macrophyte roots. Organic N is mineralized to ammonia by hydrolysis and bacteria degradation. Nitrates are then converted to nitrogen gas (N_2) and nitrous oxide (N_2O) by denitrifying bacteria in anoxic and anaerobic zones (Koottatep, 2004) which usually occur in limited oxygen supply. Nitrogen is also taken up by plants, incorporated into the biomass and released back as organic nitrogen after decomposition. Other removal mechanisms include volatilization and adsorption. Typically, these mechanisms are generally of less importance than nitrification - denitrification, but they can be seasonally important (Kadlec and Knight, 1996).

In 1999, researchers at the Gist-Brocades in Delft, The Netherlands discovered a new reaction to be added in the nitrogen cycle that called A*nnamox (*anaerobic ammonia oxidation*) Reaction*. More recently, Wendong and Jing (2009) found that integration of partial nitrification and anaerobic ammonium oxidation (Annamox) in constructed wetlands creates a sustainable design for nitrogen removal. The previous observations of high ammonia removal in constructed wetlands under anaerobic and low-oxygen conditions were attributed to partial nitrification (conversion of ammonium to nitrite, or nitritation) and Anammox, in addition to nitrification and denitrification (Chiemchaisri *et al.,* 2009; Wendong and Jing, 2009). Nitrifiers and Anammox bacteria may be natural partners in many oxygen-limited situations (Schmidt *et al.,* 2002). At the concentrations of dissolved oxygen in the subsurface flow wetlands, nitritation and nitrification could take place in the bulk water, while Anammox could occur in the deep layer of bio-films developed from gravel media in wetlands. Ammonia that removed will be converted to nitrite and nitrate. Mass balance analysis for nitrate plus nitrite, confirms that nitritation, nitrification and Anammox were responsible for nitrogen removal in the subsurface flow wetlands (Wendong and Jing, 2008).

Completely autotrophic nitrogen-removal over nitrite (CANON) is closely related to Anammox process in which ammonium is first partially oxidized to nitrite, then transformed with remaining ammonium into dinitrogen by *planctomycetelike* bacteria (Guangzhi, 2007) growing in anaerobic zones in treatment system. Unlike the Anammox process, CANON can occur in a single stage aerobic system. Considering that wetland contains a network of intermeshing aerobic, anoxic, and anaerobic zones within the same system, it provides an ideal habitat for the coexistence of different microbial communities. The stoichiometry of the CANON is given in equation 1.0 (Third *et al.,* 2001). Since CANON process could generates dinitrogen gas, the losses of total nitrogen is expected to occur in natural process (Guangzhi, 2007).

$$NH_4^+ .+ 0.85\ O_2 \rightarrow\ 0.435\ N_2 + 0.13\ NO_3^- + 1.3\ H_2O + 1.4H^+ \text{...eq 1.0}$$

However, many of the earliest SFCW were only required to remove BOD and total suspended solid (TSS). In some cases, their permits have since been revised to require the ammonia removal (Koottatep and Polprasert, 1997). Many of these new systems also have ammonia limits depending on receiving water requirements. The limiting factor in ammonia removal via nitrification is believed to be the availability of oxygen in the media profile. Some study found that the excellent ammonia removal is based on plant roots (which typically abundance of oxygen) throughout the profile, and sufficient hydraulic retention time (HRT) to complete the reactions (Konnerup *et al.,* 2009; Brix *et al.,* 2007). However, there is no consensus on how much oxygen can be furnished by the vegetation in SFCW or on the oxygen transfer efficiency of various plant species. Suwasa *et al.* (2008a) demonstrated that the surface area must be large enough to secure a sufficient oxygen transfer to cover the need for microbial degradation of organic matter and nitrification of ammonium. They also found that the removal efficiencies of N decreased when the system operated with higher hydraulic loading rate (HLR) (Suwasa *et al.,* (2008b).

2.2 Phosphorus:

The removal of phosphorus is important since it is known to be major limiting nutrient for algae growth in freshwater ecosystems (Wetzel, 2001). Wetlands remove phosphorus through biological, chemical and physical processes. Sediment burial is considered to be the major long-term phosphorus storage in wetlands (Reddy *et al.,* 1999). However, part of the sediment organic phosphorus can be mineralized to dissolved inorganic phosphorus, which can subsequently be partially released back to water (D'Angelo and Reddy, 1994; McLatchey and Reddy, 1998).

The major processes responsible for phosphorus removal in SFWC are typically by adsorption, precipitation and plant up-take rates. The frequent filtration materials used in SFCW is gravel, which commonly good in absorption compared to the plant roots (Vymazal, 2004). Phosphorus is an important nutrient required for plant growth and is usually act as a limiting factor for vegetative productivity. Phosphorus is transformed in the wetland by a complicated biogeochemical cycle. Accordingly, most of the researcher claimed that wetlands are not efficient in phosphorus reduction (Kadlec and Knight, 1996). However, wetlands are not long-term removal solution for phosphorus as compared to nitrogen. In the past, if the system operate in a longer periods (maximum of 9 years) the phosphorus removal will decrease over years probably because of limited sorption capacity. The amount of phosphorus removed is not more than 5% of the total removed phosphorus in the beginning of wetland operation. As the sorption decreases over years and macrophyte biomass increases simultaneously, the phosphorus bound in biomass becomes higher but it rarely exceeds the level of 20% of the total phosphorus removed (Binhe, 2008; Richardson and Qian, 1999).

Phosphorus removal in most constructed wetland systems is also not very effective because of the limited contact between the contaminant in wastewater and the soil. Some experiment and developmental work has been undertaken using expanded clay aggregates and the addition of iron and aluminium oxides. Some of these treatments are promisingly but the long-term expectations have not been observed so far (Vymazal, 2004). Some systems uses sand instead of gravel to increase the phosphorus retention capacity, but selecting this media would reduce the hydraulic conductivity of sand compared to gravel (EPA, 1993). Therefore, a wide land area is required in order to remove the phosphorus.

3.0 Construction, Operation and Maintenance:

3.1 Construction:

Construction of SFCW includes physical design, hydraulic design and physical construction of the wetlands. Designing the wetlands is the critical phase of the implementation process. Because of the nature of SFCW wetlands, errors made in the early stages of construction become almost impossible and very expensive to correct after the bed media is installed. As a result, a clear understanding and correct execution of the design documents are essential. Many texts and design guidelines for SFCW have been published such as USEPA, (2000), EC/EWPCA (1990); WPCF (1990); Reed *et al.* (1995); Kadlec and Knight (1996); Campbell and Ogden (1999), however, there is no guidelines recorded for tropical climates. Therefore, much misconception about their application, design and performance has been occurs in the initial design of SFCW. The misconception that almost occurs is about the availability of oxygen in SFCW and the ability of SFCW to remove significant amounts of nitrogen.

Physical construction includes elevations and grading, liners, berms, vertical sidewalls, influent and effluent piping, bed media placement and installation of control structures. The major consideration in the construction of wetlands is excavation and grading. The setting of the correct elevation of each basin, pipe and control structure is one of the most fundamental and critical aspect. The next major consideration is distribution piping and effluent collection piping. For most SFCW, the drainage pipes are installed prior to placement of the various layers of bed media and the influent distribution piping is typically installed in top of the bed. Another aspect on wetlands construction is selection of media type and size which is very critical to the successful performance of the system. This is especially true for vertical flow of SFCW, which rely on stacked layers of filter materials that often, has to meet a quite tight grain-size distribution (Kaldec and Wallace, 2009). Unwashed crushed stone has been used on a large number of projects and washed stone or gravel is preferred. Coarse aggregates for concrete construction are commonly available and would be suitable for construction of SFCW systems. The recent trend toward the use of larger sizes of rock is believed due to the impression created by the surface flow conditions on many of the early systems. It was apparently thought that the surface flow was caused by clogging and that the use of a coarser rock with larger void spaces and a higher hydraulic conductivity would overcome the problem. In most cases the problem has not been overcome since the hydraulic gradient provided is too small. The use of smaller rock sizes has a number of advantages in that there is more surface area available on the media for treatment, and the smaller void spaces are more compatible with development of the roots and rhizomes of the vegetation, and the flow conditions should be closer to laminar (EPA, 1993).

3.2 Plants selection:

One of the most important aspects of the start-up of SFCW system is vegetation selection and establishment. The selection of plant species in SFCW is often a product of cultural and regulatory constraints. In tropical countries, locally available species of *Pragmites, Cyperus, Bulrush* and *Typha* have been the most common choice to date. Most recently, Konnerup *et al.* (2009) successfully used *Helicornia Psittacorum* and *Canna Generalis* in order to increase the ecstatic value of wetlands and to increase the local people's awareness of wastewater treatment in Thailand. The selection of a plant species is generally a function two factors which is the degree of rhizome spread and the ability to achieve plant canopy and crowd out unwanted invasive species and another factor is to develop more belowground root biomass and depth of root penetration, which benefit wastewater treatment.

The most important functions of the plants are related to their physical effects in the wetlands. The roots provide a huge surface area for attached microbial growth, and in temperate regions the plant litter provides an insulation layer against frost during winter. Plants can also facilitate aerobic degradation by releasing oxygen to the rhizosphere, but oxygen release rates are difficult to quantify and the overall effect on pollutant removal is probably varying (Brix, 1990). Regarding uptake of nitrogen (N) and phosphorus (P) many studies in temperate climates have shown that the amount which can be removed by harvesting is generally insignificant (Tanner, 2002). However, in tropical climates where the plants grow faster and throughout the year, the up-take of nutrients can probably contribute to significantly higher removals of nutrients as has been reported in several studies (Koottatep and Polprasert, 1997; Kantawanichkul *et al.,* 2001; Kyambadde *et al.,* 2004). However, if the plants are not harvested the incorporated nutrients will be released again during decomposition of the biomass.

3.2 Operation and Maintenance:

SFCW have few operation and maintenance requirements, but maintenance must be performed properly to ensure system performance. Operation may entail alternating cells or adjusting water levels and harvesting vegetation. Some systems may have banks and berms that need to be maintained, and inlet and outlet structures that should be cleaned periodically.

Water level and flow control are usually the only operational variables that have a significant impact on a well designed constructed wetland's performance. Changes in water levels affect the hydraulic residence time, atmospheric oxygen diffusion into the water phase, and plant cover. Significant changes in water levels should be investigated immediately, as they may be due to leaks, clogged outlets, breached berms, storm water drainage, or other causes (EPA, 2000).

Routine maintenance of the wetland vegetation is not required for systems operating within their design parameters and with specific bottom-depth control of vegetation. Wetland plant communities are self-maintaining and will grow, die, and regrow each year. Plants will naturally spread to unvegetated areas with suitable environments (e.g. depth within plant's range) and be displaced from areas that are environmentally stressful (Merlin, 2002). The primary objective in vegetation management is to maintain the desired plant communities where they are intended to be within the wetland. This is achieved through consistent pre-treatment process operation, small, infrequent changes in the water levels, and harvesting plants when and where necessary. Where plant cover is lacking, management activities to improve cover may include water level adjustment, reduced loadings, pesticide application, and replanting (EPA, 2000; Moore, 1999).

4.0 Application of Different Wastewater Types:

4.1 Landfill Leachate:

Landfill leachate is typically formed from infiltration waters and the products of solid-waste decomposition. Those contaminants leachate waters are a potential threat to surface and subsurface receiving waters. New landfill leachate (<10 years) contains large amount of free volatile fatty acid (VFA), resulting in high concentration of chemical oxygen demand (COD), BOD, ammoniacal-nitrogen (NH_3^-N) and alkalinity, a low oxidation-reduction potential and black colour

(Wang, 2004; Nazaitulshila, 2006). Therefore, biological processes are commonly employed for new landfill leachate treatment to remove the volume of biodegradable organics. Old landfill leachate (>10 years) or biological treated new landfill leachate has a large percentage of recalcitrant organic molecules. It is characterized by high COD, low BOD, fairly high NH_3^-N and alkalinity, low ratio of BOD/COD, a high oxidation-reduction potential and dark brown or yellow colour (Wang, 2004; Chew, 2006). Figure 2 show typical landfill leachate characteristics over time and Table 2 presents the typical concentration ranges of chemical parameters in landfill leachate.

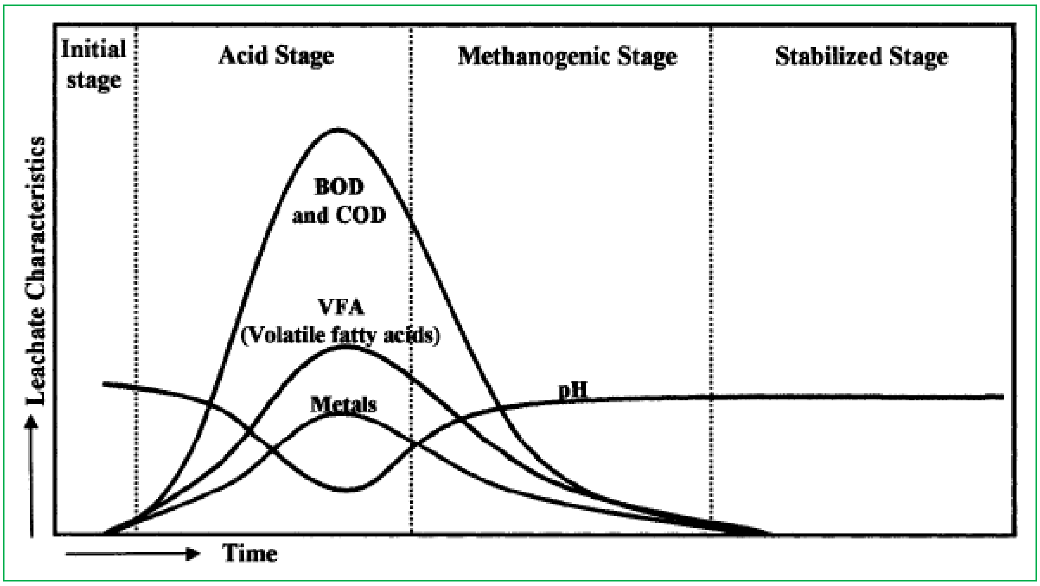

Figure 2: Typical Landfill Leachate Characteristics over Time (Adapted From Tchobanouglous *Et Al.*, (1993)

Table 2: Typical Characteristics of Landfill Leachate in Thailand (Kjeldsen *Et Al.,* 2002)

Parameter	Composition
pH	4.5-9.5
TS	2,000-60,000
TDS	1,000-20,000
COD	140-152,00
BOD_5	20-57,700
BOD_5/COD	0.02-0.87
TKN	65-4,700
NH4-N	0.0-2,200
Sulphide	n.d*
Mercury	0.2-50
Lead	0.01-5
Cadmium	0.0001-0.4
Nickel	0.1-13

All values in mg/l except pH and BOD_5/COD; n.d* - not detected

Natural wetlands are often the recipients of landfill leachates because many landfills are adjacent to wetlands or partially fill them. However, previous studies were investigated on different aspects of constructed wetlands, including the effects of soil composition and grain-size distribution, removal mechanisms, fate of pollutants, engineering aspects and hydraulic distribution and flow. SFCW are the most used due to absence of odours and mosquitoes, simple operation and maintenance, reliable operating conditions and a combination of aerobic and anaerobic processes inside the system. This aerobic-anaerobic environment in wetlands allows high removal rates of different organic compounds, pathogens and some low-degradable matter. Lately, Yalcuk *et al.* (2009) demonstrated that SFCW is the most excellent alternative treatment in leachate since vertical systems performed better in ammonium removal whereas, the horizontal system was better for organic removal.

4.2 Domestic Wastewater:

Domestic wastewater contains liquid and water which carries waste from various types of components. It may be purely domestic in origin or it may contain some industrial or agriculture wastewaters. In appearance, domestic wastewater is a grey turbid liquid which contains materials such as suspended solids (SS), biodegradable and refractory organics, nutrients, inorganic matter and as well as microorganisms. The organic and mineral matter constitutes about 0.1% of the domestic wastewater and the other 99.9% is mostly water (Metcalf and Eddy, 1991). Domestic wastewater in tropical climates country has a low organic content compared with typical sewage (Giri *et al.,* 2006). However, this is a fundamental fact that seems not to have been fully appreciated by local engineers. Climatic conditions such as high temperatures and heavy rainfall have resulted in a further reduction in the organic content of the wastewater. This is due to decomposition and dilution, and the fact that tendency to follow western-style wastewater treatment practices in the urban areas can be determined (Giri *et al.,* 2006).

SFCW are gaining more popular because it is a low-cost maintenance technology for on-site treatment of septic effluents. More recently, Konnerup *et al.* (2009) have tested on horizontal SFCW at the Asian Institute of Technology (AIT) campus in Bangkok, Thailand. A result of these investigations indicates that the organic load, fecal coliform populations and the N and P concentrations of the septic water decreased considerably by passing through the wetlands. Constructed wetlands can reduce BOD5 of septic water by 80±90% which provided for feasible disinfection by chlorination. Reduction in populations of fecal coliforms varied but generally, populations were reduced by 90±99%. Chlorination further reduced populations of fecal coliforms to less than 2 cfu/100 ml. Constructed wetlands provided an effective method for secondary treatment of on-site domestic wastewater.

4.3 Industrial Wastewater:

Industrial wastewater can be defined in category of food-processing wastewater, iron and steel industry, wood industry, pulp and paper industry, mines and quarries, complex organic chemicals industry and nuclear industry. Industrial wastewater treatment covers processes of wastewater treatment to treat waters that have been contaminated in with anthropogenic industrial or commercial activities prior to its release into the environment. The wetland application on food-processing wastewater is not popular yet in tropical country. Wastewaters generated from food operations have typical characteristics of common municipal wastewater. It is merely biodegradable and nontoxic, but has high concentrations of BOD and SS. The constituents of food wastewater are often complex to predict due to the differences in BOD and pH, e.g. from vegetable, fruit, and meat products and due to the seasonal nature of food processing and post harvesting. Processing food for sale produces wastes generated from cooking which are often rich in plant organic material and may also contain salt, flavourings, colouring material and acids or alkali. Very significant quantities of oil or fats may also be present.

Considering the quality of design and construction of SFCW in tropical climates, not much information can be derived from this food- processing wastewater. Horizontal SFCW were tested by Vrhov *et al.* (1996) with a major concern of food waste. The experiment was started with the wastewater flows from the primary sedimentation basin into the first bed due to gravity. The water then flows under the surface of the substrate to the end of the first bed and into the second bed. At the end of the second bed, a drainage tube for the collection and outflow of purified water into the outlet sump is placed into a 1 m wide layer of rough stone. The pollution decreased with regard to COD by 92%, BOD5 89%, orthophosphate 96%, ammonium 86% and nitrate 65%. The microbiological parameters indicated that the total number of coliform bacteria is reduced by 99% and the number of *faecal streptococci* by 98%.

5.0 Technology in Wetlands Application:

5.1 Geographic Information System (GIS) Application:

The importance of the wetland environmental protection has been extensively recognized, computer technologies have been widely used in environmental protection, and a large number of the wetland information systems have been developed. In the United State, almost every state has developed wetland information system. For example, the University of Florida created the Aquatic, Wetland and Invasive Plant Information Retrieval System (APIRS), Texas created the Texas Wetland Information Network (WetNet) and California Resources Agency developed the California Wetlands Information System (CWIS). Montanan wetlands committee initiated and developed the Montanan Wetland Information System (Wang *et al.,* 2005). Louisiana developed the wetland comeback Spatial Decision Support System (Lyon *et al.,* 1995). At the same time, many other countries developed their wetland information systems such as Turkey used ArcView

GIS to create the Wetlands of Turkey Geographic Information System (TUSAP-GIS), India developed the National Wetland Environmental Information System (ENVIS), Canada created the Canadian Information System for the Environment (CISE) and Six European countries (Greece, Germany, Sweden, Rumania, England, and Holland) developed Wetland Evaluation Decision Support System (WEDSS) (Wang *et al.,* 2005).

In Malaysia, a research by Aminu, 2007 on Ramsar Site involving Sungai Pulai in the state of Johor was done using the GIS application, with emphasis on sustainable wetland issues. The study demonstrates that GIS can be an effective tool in preserving and monitoring green and open spaces in an urban area. The study was approached from the aspect of natural resources management and eco-tourism development potential using GIS. The GIS database components developed for the study include site and administrative boundaries, physical and biophysical elements (flora and fauna layers), planning and legislative elements, hydrology (water bodies, river reserve and river), environmental quality and resources, tourism (recreational activity, tourism facilities, and tourism resources), transportation (road and seaport), socio-economy and local community, and infrastructure and utility (electrical line reserve, telecommunication, water supply, sewerage and waste disposal).

5.2 Compost Material:

Compost is a combination of food material and other organic material that is being decomposed through aerobic decomposition into a rich black soil (Aslam *et al.,* 2008). Compost soil is very rich soil and used for many purposes. A few of the places that it is used are in gardens, landscaping, horticulture, and agriculture. The compost soil itself is beneficial for the land in many ways, including as a soil conditioner, a fertilizer to add vital humus or humic acids, and as a natural pesticide for soil (EPA, 1997). In ecosystems, compost soils are useful for erosion control, land and stream reclamation, wetland construction, and as landfill cover.

Amending wetland soils with compost in wetland restoration projects is potentially a high value added to end use application for composted organic waste. Compost adds humus and nutrients that plants need to re-establishes themselves in decimated areas. Compost with its high organic contents, can absorb up to four time its weight in water and can replace essential organic material in wetlands. Aslam *et al.,* (2008) used organic compost material compare with gravel base as a filtering media in the SFCW. The average performance of the treatment for TSS exceeds 60.5% and 48.5% for compost based and gravel based, respectively, for COD it exceed 52.5% and 47.5% and for BOD it exceeds 56% and 45% for compost based and gravel based, respectively. This shows the removal performance of the compost based system was good compared to gravel based system.

5.3 Bio-Particle Application:

Bio-particle is considered as green technology and also recognized as environmental friendly process, natural and reported as more economical method for wastewater processes. Bio-particle is developed recently similar with the trickling filter technology which enables to treat low strength of wastewater and high micronutrient contents. Bio-particle emphasizes on the use of indigenous/ bio-augmentated microbes immobilized on bio-particle to enhance wastewater treatment in the biodegradation process. In principle, bio-particle comprised of natural zeolite, slake lime and activated carbon immobilized with microbes. Zeolite will absorb the organic substances and act as chemical filter which control cation such as sodium, potassium, barium and calcium and also large molecule such as water, NH_3, CO_3^{2-} dan NO_3^-. Besides act as chemical filter, zeolite can also act as ion exchange, censor, odour removal and gas absorption. The slaked lime ($Ca(OH)_2$) is used to incerease the pH value and then removes the impurities such as phosphorus and sulphate and finally the activated carbon could adsorb colour and organic pollutants.

Recently, Nadirah *et al.* (2008), applied the bio-particle onto bio-filter system as a filtering media to treat domestic wastewater and the result are as shown in Table 3. Effectiveness of bio-particle to treat and improve the water quality is depends on the selection of the support material capable of maintaining a high amount of active biomass and a variety of microbial populations. The selection of useful microorganisms is also important to degrade or mineralize the pollutants. Types of microorganism that can be used in treating wastewater are *Pseudomonas putida, Pseudomonas fluorescens, Xanthobacter sp,* and *Rhodococcus rhodochrous*.

Therefore, the combination of bio-particle and subsurface flow constructed wetland is as an alternative method since bio-particle has been reported to effectively remove most of the recalcitrant compounds such as alkyl groups, benzene ring substances, sulphate, phosphate and nitrate and constructed wetlands have also been proven to be an effective low cost treatment system which utilizes the interactions of emergent plants and microorganisms in the removal of wastewater pollutants. The used of bio-particle also seem can promise in reducing the space area and land acquisition.

Table 3: Experimental Result from a Biofilter System (Nadirah, 2007)

Parameters	Before	After	% removal
pH	5.05	7.73	-
BOD	158	62	61
COD	334	10 l	97
Ammonia	1.694	0.230	86
TSS	272.6	80	71
Turbidity	113	21	89
Oil and Grease	214	100	53
Nitrate	0.4	0.2	50
Sulphate	1.8	0.0	100
Phosphate	0.316	1.970	-

All values in mg/l except pH and Turbidity in FAU

6.0 Conclusions:

Wetlands for wastewater treatment are deceptively simple. They have the complexity that all ecological systems possess, and being a relatively new technology further research and development studies need to be conducted. For example, there is conflicting and limited data on the impact of temperature which is not well understood, and wetland designers and engineers have developed a number of conflicting formulas for determining size and hydraulics of constructed wetlands in different climatic regimes. Therefore, research is urgently needed to further advance and understand the SFCW concept. Below are suggested researches that have been discussed which are high priority needed:

- As reported in most of the study, the SFCW system does not establish reliable for treating wastewater with high ammonium concentration. Most operational SFCW demonstrating successful ammonia removal at long HRT, which usually takes more than six days. From the review, intermittent or batch type flow to alternating beds might enhance the oxygen status and therefore, improve the ammonia removal capability. Therefore, the approach should be tested and then demonstrated if promising.
- It is likely that some oxygen is available from the plant roots to support nitrification reactions. Effective use of that oxygen source requires complete development of the root zone in the bed profile and sufficient detention time. Neither condition is present in most operational SFCW systems. Further research is necessary to optimize these relationships.
- Further research and a better understanding is primarily needed for nitrogen removal and nitrogen transformations occurring in these SFCW systems especially the information in tropical climates which is very limited and there is also some misconception on the oxygen available from the plants to support nitrification reactions.
- The use of new technology and specialized media in the SFCW to improved phosphorus removal should be developed and demonstrated since phosphorus removal always shows worse performance in the removal.
- Although recent studies in the construction of SFCW indicate that the use of a coarser rock with larger void spaces and a higher hydraulic conductivity will contribute minimal clogging in the beds investigated, the effort needs to be continued to determine the long-term risks of clogging.
- Operation and maintenance are the most important aspect of treatment wetlands operation. It is becoming apparent that SFCW will require de-clogging one or more times during a 20 year life span. Method for removing solids are currently high needed.
- SFCW design can offer high performance levels for various types of wastewater. However, the response to complex organic and inorganic compounds in industrial and domestic wastes needs more investigations.
- Further researches in applying new technology are needed to reduce the wetlands area and land acquisition since most of SFCW require large area and it is not suitable for urban area.

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